GDV
Unfallforschung
der Versicherer

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Distraction due to vehicle operation

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Introduction

An increasing number of communication, comfort and driving assistance systems are being installed in vehicles. They are designed to support drivers and improve road safety. These systems are operated by Human Machine Interfaces (HMI) and touch displays are used as standard in such applications. They can be easily updated with the latest software by manufacturers and permit the integration of many different functions. Even basic driving tasks are becoming increasingly digitalised, such as windscreen wiper adjustment or windscreen heating. However, it is not possible to use touch displays without looking away from the road, unlike in the case of levers and switches. If functions are hidden deep in the menu then driver must also look away from the road for a correspondingly long time. Taken together, this poses potential risks for road safety [1].

Distraction and Inattention are regarded as a main risk for traffic accidents. In 2021 in Germany, a total of 5,987 accidents with personal injury were registered with distraction as an accident cause. Of these, 970 were due to the use of electronic devices and 5,017 to other causes [2]. Even though these figures are mainly based on police-officer assessments of the causes of these accidents and are therefore subject to bias, research studies and figures from outside of Germany also indicate that distracted driving is a widespread problem and that distracted drivers are at higher risk of accidents [1,3]. Currently there are no regulations or mandatory best practice that define how to design increasingly complex HMI that distract drivers as little as possible from their driving tasks. Therefore, the German Insurers Accident Research (UDV) commissioned HFC Human-Factors-Consult GmbH to investigate what design guidelines for avoiding distraction already exist and what needs to be done to ensure their implementation.

1. Research aim and methodology

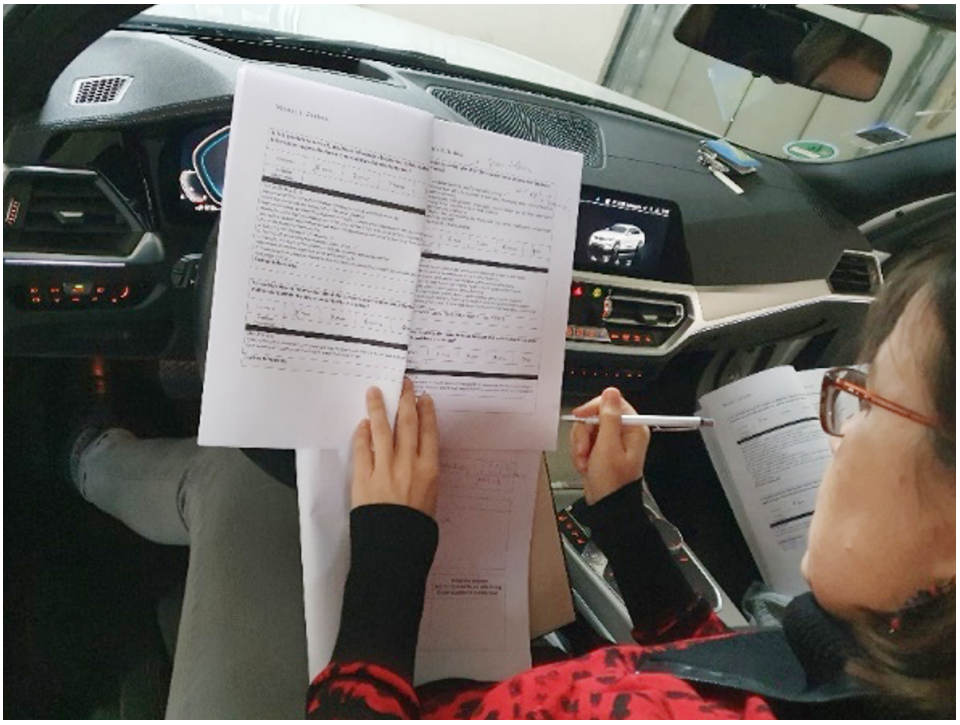
The aim of the research project was to derive guidelines for assessing distraction resulting from HMI design, especially for basic driving tasks. The aim is to develop draft guidelines which can be easily applied in practice. The intention is that the guidelines should be used to evaluate the HMI with regard to their potential for distraction and to identify areas for improvements.

To this end, existing guidelines dealing with distraction as a consideration in the design of HMI were first reviewed. Second, interviews were conducted with nine experts from vehicle manufacturer (OEMs) and industry-oriented research organisations involved in the design and testing of in-vehicle HMI. They were asked to assess the currently available guidelines and to identify requirements not hitherto addressed. Based on these two steps, guidelines were drafted in the form of a checklist for assessing distraction resulting from HMI use. The checklist was pre-tested on two different in-vehicle HMI (Fig. 1). The results were discussed with the experts and the checklist revised.

The extended research report (in German) can be found at www.udv.de [4]

Testing the checklist

Figure 1 · Practical testing of the first draft of the checklist in the vehicle



2. Results

2.1 Overview of existing guidelines

There are various international guidelines that address the low-distraction design of the HMI in vehicles. These can be divided into three categories. The first category (Type I guidelines) includes widely used guidelines that define, among other things, how HMI should be installed, how information should be presented to optimum effect, and how the system should interact with drivers. These are collections of criteria that can be used to evaluate the performance of an HMI. They include, for example, the European Statement of Principles (ESOP)[5] or the National Highway Traffic Safety Administration's (NHTSA) Guide to Visual-Manual Distraction[6]. Both are freely available and widely used, but also address many other ergonomic and usability issues in addition to distraction. The NHTSA guideline is a comprehensive document of over 70 pages detailing the requirements for the systems in text form. The ESOP also includes detailed descriptions of system-requirements and provides guidance on their testing. The second category of guidelines (Type II guidelines) consists of specific design guidelines, some of which explicitly address distraction avoidance. However, these are less widely used. They include, for example, the TRL guideline for the evaluation of in-vehicle information systems[7]. The TRL is based on the ESOP in terms of content but presents this content using short questions that the person completing the form can answer in order to evaluate the systems. The third category of guidelines (Type III guidelines) consists of individual recommendations, most of which are derived from empirical studies.

Regarding the applicability of the guidelines, it should be noted that those in the first two categories are at least ten and, in some cases, even 20 years old and do not reflect the rapid progress of technology. They relate to visual-manual distraction, especially by infotainment systems, and follow the principle that one device operates one or only a few functions (e.g., switch to operate the radio). Highly integrative systems, such as multifunctional touch displays, are not considered, although they have since become standard. The problems associated with such systems, such as deep menu structures, are not addressed. Since the guidelines cover devices and not the operation of individual functions, it remains unclear which functions are addressed and how they should be implemented to be as distraction-free as possible. In addition, alternative input modalities, such as voice control systems, are not included. The individual recommendations in the third category all refer to specific individual systems or very detailed sub-aspects of the HMI and are not generally applicable.

2.2 Current practice and needs

In practice, the currently established guidelines are used for the development and testing of HMI in vehicles. The ESOP and the NHTSA guidelines are particularly worth mentioning here. However, the advanced age of the guidelines poses a problem, as multifunctional devices and more recent interaction concepts are not covered. Developers and manufacturers therefore additionally use internal documents and knowledge databases, which are not publicly accessible. Customer demands for centralised touch displays partly conflict with road safety requirements. Manufacturers need to integrate a wide variety of functions into one single device. HMI are therefore becoming increasingly complex and the number of menu levels is growing. In some cases, touch displays are also combined with voice control systems. However, voice control is currently often regarded as a bonus rather than a standard feature. In the future, haptic touch displays are also expected to emerge. Overall, however, customers still want centralised displays.

According to experts, there is a need for an easy-to-use tool for applying the guidelines, for example based on the NHTSA document. Additionally, knowledge about specific design measures needs to be more easily available. Even if internal checklists are already used in development, there is a lack of publicly accessible checklists and knowledge databases that would permit comparisons between solutions and the exchange of knowledge.

2.3 Derived requirements for an instrument

Based on the research and interviews with experts, the following requirements have been derived for a tool used to assess the distraction potential of HMI:

- **Form of guideline:**
  Type I guidelines, due to technology openness, widespread familiarity, and accessibility,

- **Openness to different and more recent input modalities:**
  it should be possible to assess input via physical input elements as well as touch display and voice control,

- **Focus on distraction:**
  the instrument must relate specifically to distraction potential,

- **Practical applicability:**
  manufacturers, developers and test institutions (e.g. EuroNCAP) must be able to use the instrument in practice,

- **Focus on functions:**
  it must be possible to test individual functions independently of the hardware,

- **Different implementation requirements depending on function:**
  individual implementations of the HMI are recommended for each function that is to be be tested.

2.4 Development of a low-distraction HMI design tool

Formal aspects and application

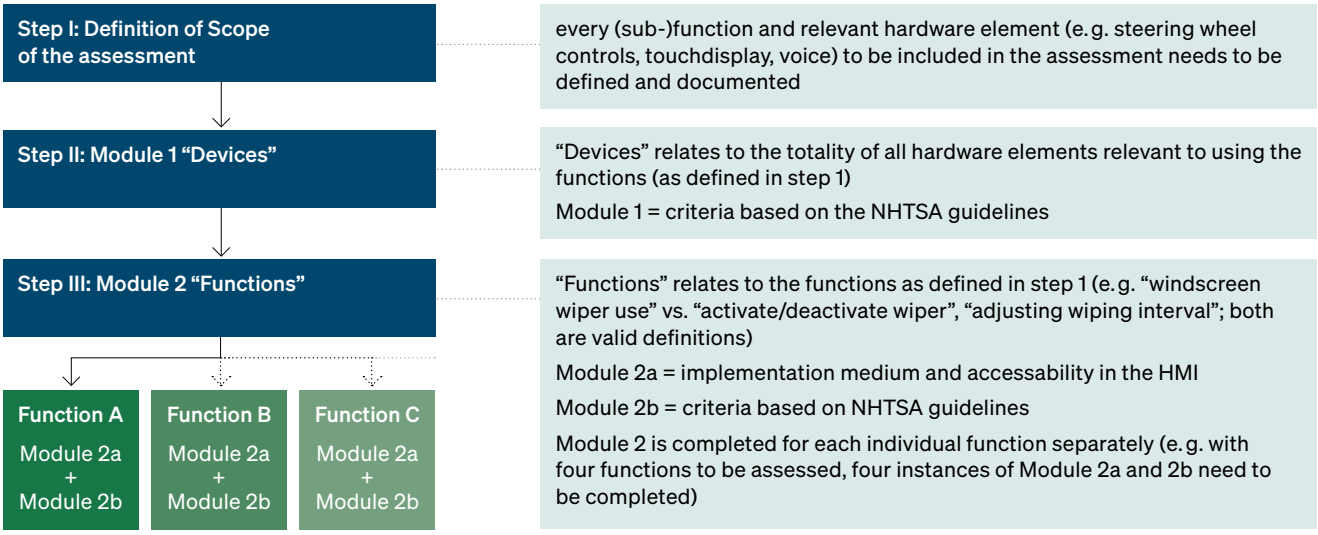
Based on the results of the research and the needs identified in the expert interviews, the instrument for assessing the distraction potential of HMI was developed in the form of a checklist. The checklist is based on the distraction-related content of the NHTSA guidelines[6], which were identified and compiled for this purpose. However, the form of the individual items to be completed is based on the practice-oriented TRL guideline[7]. Consequently, the developed checklist focuses on the potential for distraction, has a user-friendly format, and can be completed in a comparatively short time. The target user group is HMI experts who are already familiar with the existing guidelines on which the checklist is based. They evaluate the distraction potential by making a subjective expert judgement. Unlike the previous guidelines, the checklist distinguishes between devices and functions. This means that each function delivered by one and the same device can be evaluated individually. The checklist is equally applicable to all types of functions. This means that not only infotainment functions but also basic vehicle operating functions (e.g., operating turn signals) can be explicitly evaluated. The checklist is able to cater for input modalities such as switches, touch displays or voice input systems and is available in English.

Structure of the checklist

The checklist begins with an introductory text explaining the procedure. Figure 2 provides an overview of the structure of the checklist and the modules it contains. The user starts with identifying the precise function that is to be evaluated and the associated device(s). A separate evaluation is performed for each function. In addition, the test condition is entered in the overview (e.g., stationary vehicle vs. evaluation while driving).

Structure/Outline of the checklist

Figure 2 · Checklist: Overview of the structure in the introduction section



Module 1: Devices

The introduction and definition of the scope is followed by Module 1: Devices. In this module, the devices are evaluated based on eleven items. Devices can be different types of operating element, such as touch displays or switches. If several options exist, for example if operation is possible via a touch display as well as via a switch on the steering wheel, all of them are evaluated. Figure 3 shows an example item. First, the corresponding design criterion from the NHTSA guidelines is listed. Any concerns regarding low-distraction implementation, even for just one of the control options, are indicated on a three-point scale (none, minor, serious). In addition, it is possible to indicate that clarification is still required, for example if the corresponding evaluation was not possible (subject to clarification), or the item is not applicable (not applicable). There is a free-text area in which the problem can be described in more detail and more detailed information or references are given below this. The following aspects are covered, among others:

- → The visual display of driving-relevant information is in the driver's line of sight.
- → The viewing angle of the device complies with NHTSA requirements.
- → The noise level does not mask warnings, muting is possible.
- → One-handed operation is possible.
- → Information not relevant to safety can be hidden or disabled.

Checklist: Sample item for device evaluation

Figure 3 · Device requirement, assessment of concerns and description

1. No part of any of the physical devices, when mounted in the manner intended by the manufacturer, should obstruct a driver's view of the roadway. (NHTSA 2013 V. A1)					
Concerns:	◯ none	◯ minor	◯ serious	◯ subject to clarification	◯ not applicable
Concern Description:					
Further References:					

Module 2: Functions

In Module 2, the functions are then evaluated. The evaluation is subdivided into Module 2a and Module 2b. In Module 2a, the implementation of the function is evaluated (see section Module 2a). In Module 2b, the distraction potential of the corresponding function is evaluated on the basis of 17 items. Figure 4 shows an example. The formal structure of the items corresponds to that used in Module 1. In terms of content, the following aspects are addressed, among others:

- Non-driving functions are disabled while driving.
- The texts fulfil the readability criteria according to ISO standard 15008:2003.
- Multistep functions can be interrupted and resumed at a logical point.
- If multistep functions are interrupted, there is no loss of partial inputs.
- Inputs are confirmed promptly (0.25 seconds).
- Notification of the system response is given if the system's response time is more than two seconds.

Checklist: Sample Item for Function Assessment

Figure 4 · Function requirement, assessment of concerns and description

15c. Drivers should be able to initiate commands that erase driver inputs during multistep function use.. (NHTSA 2013 V. J2)					
Concerns:	◯ none	◯ minor	◯ serious	◯ subject to clarification	◯ not applicable
Concern Description:					
Further References:					

Module 2a: Decision tree for function implementation

In Module 2a, a decision tree is used to additionally evaluate the implementation of the respective functions. Figure 5 shows the representation in the checklist. Depending on the framework conditions for the use of the function in question, a recommendation is derived indicating which implementation of the HMI reaches the minimum criteria for acceptability ("is minimally acceptable"). The framework conditions are first clarified using test questions. The test questions are answered with 'Yes' or 'No'. Abbreviated forms of the questions are shown in the grey boxes. The answers lead to the minimum acceptable implementation based on the paths in the decision tree. The acceptable minimum implementation is divided by the dashed lines between the red, the yellow and the green boxes. The minimum acceptable implementation should be ticked in the boxes on the right-hand side. The current or planned implementation is selected in the boxes on the left-hand side. The comparison between the two sides shows whether there is a need for optimization. The application is illustrated using the example "Changing the windscreen wiper interval". The questions are as follows:

1. **External reason for use:** is the use of the function due to external factors beyond the driver's control and not a voluntary decision made by the driver?
   – Yes, visibility is degraded due to an external cause, i.e., precipitation.

2. **Time criticality:** is immediate use of the function (within 10 seconds maximum) required after the triggering event?
   - Yes, visibility must be restored immediately.

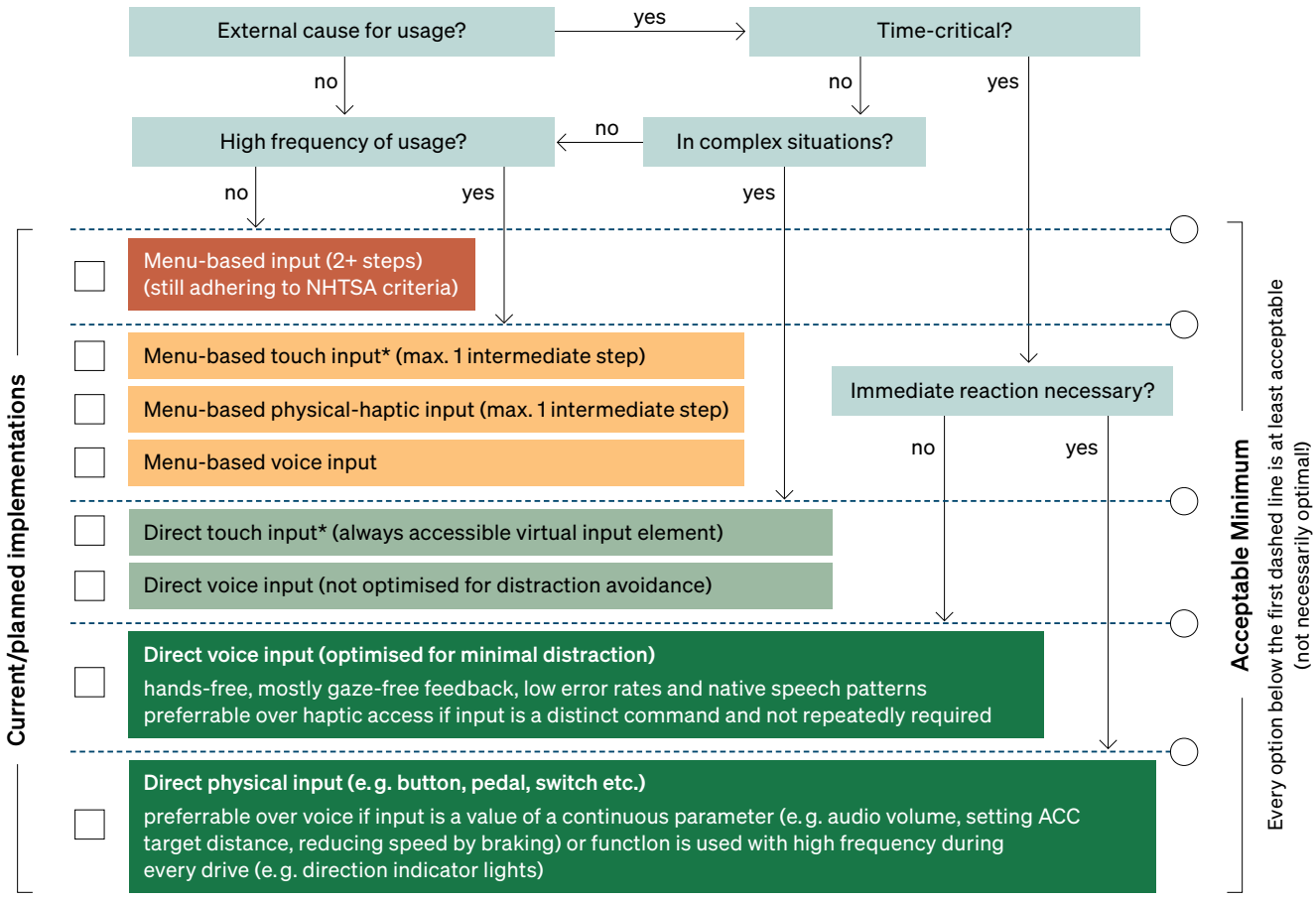
3. **Immediate response:** is an immediate response by the driver required?
   - Yes, the driver must be able to restore visibility immediately by himself/herself.
     - Bottom level outcome: direct physical input is recommended.

4. **Situational complexity:** is the function typically used in or caused by challenging driving situations (e.g., at intersections, on motorway slip roads)?
   - Yes, limited visibility represents a complex situation.

5. **Frequency of function use:** is the function used frequently (on almost every trip)?
   - No, precipitation is not expected on (almost) every trip.

Checklist: Decision tree for function implementation

Figure 5 · The minimally accepted implementation of the respective function can be read off from the conditions of use on the right-hand side, while the current / planned implementation of the function in the vehicle is indicated on the left-hand side.



* Can be treated as "physical input" if haptic feedback sufficient for gaze-free operation.

The implementation options in the coloured boxes differ depending on the directness of access (direct access vs. different menu levels) as well as the input modality (voice interaction, haptic input device, touch display). The higher up the implementation is presented, the higher the distraction potential. It is assumed that the implementation quality is comparable. For example, if a haptic button is very small and located between many other buttons, a large button on the touch display that is always available would possibly be the less distracting option. Implementation quality is not included in the decision tree. However, a corresponding item can be found in Module 2b.

The example of the windshield wiper interval leads to the lowest level, which corresponds to a direct physical input with a switch. Since the interval controlled by this function can be set at different (continuous) levels, physical input via a haptic lever or switch is recommended. For discrete inputs (ON vs. OFF), direct voice input using a verbal command would also be acceptable. The decision tree can also be used to prioritize the way functions are implemented. The example of the windshield wiper shows that functions that are particularly time- and safety-critical should not be integrated into a touch display but should continue to be controlled by manual levers or switches. Even if it seems technically and aesthetically advantageous, it is sensible not to implement all functions digitally. If the function to be tested has already been implemented in such an HMI then optimization is necessary.

Overall assessment using the checklist

The checklist concludes with an overall assessment in which concerns and aspects still to be clarified regarding all the devices and functions to be assessed are noted. The aspects that still need to be clarified are then subjected to a separate review. Serious concerns indicate that the appropriate HMI needs to be optimized with regard to its distraction potential. Minor concerns should be summarized and possible interrelationships should be examined. If they occur more than once they may also indicate a need to optimize implementation.

In its current form, the checklist is completed based on the subjective assessments of users. This requires appropriate expertise but also offers the advantage of being as flexible as possible in practical use.

3. Summary and outlook

As a result of this research project, an instrument in the form of a checklist was developed based on research and interviews with experts, with the aim of evaluating the distraction potential of HMI in vehicles. The checklist was tested in practice and evaluated by experts. Using the checklist, the functions and the corresponding hardware (devices) can be evaluated separately. This means that even highly integrative systems, such as multifunctional touch displays, can be evaluated efficiently. In addition, the checklist contains a module for evaluating the implementation of functions. For each function to be evaluated, it is thus possible to determine what access level and what input modality is acceptable as a minimum in order to make operation as distraction-free as possible.

Even though touch displays are increasingly being used and desired by customers, they come with a high risk of distraction. In particular when functions are embedded deep in the menu structure and can only be accessed via several intermediate steps, it is necessary to take one's eyes off the road for longer. Functions that are particularly time- and safety-critical for vehicle operation should therefore always be directly operable without intermediate steps. This is also recommended with regard to implementation of the functions. Functions that were previously intuitive to operate, such as the windshield wiper or direction indicators, should continue to be operable using direct, haptic controls, as the example of windshield wiper adjustment shows.

In its current form, the checklist can be used by manufacturers and developers for internal testing to evaluate the distraction potential of existing and future planned HMI in vehicles. However, the checklist does not include quantitative limit values. If it is to be used in the future by test institutions such as EuroNCAP, greater objectivity is necessary and appropriate evaluation criteria will have to be developed to achieve this. Empirical indicators of the distraction caused by various HMI should therefore be collected in future applied studies, for example on the basis of test drives in real traffic or in driving simulators. The results could be used to determine specific parameters for evaluating the distraction potential. To ensure that the entire driver population is represented, persons of different ages and driving experience must be included in such studies.

The checklist does not yet contain any items for evaluating voice control systems, but merely maps them in the decision tree. To date, there are no corresponding established guidelines or criteria catalogues that could be incorporated in a corresponding checklist. However, voice control systems can contribute significantly to minimizing distraction [1]. To achieve this, however, such systems must be intuitive and directly operable. If they are error-prone and require many manual corrections, operation could prove to be highly distracting. In the future, therefore, appropriate criteria for evaluating the distraction potential of voice control systems will have to be developed and incorporated in the checklist.

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